OPTIMIZATION OF PROCESS PARAMETERS AND CHARACTERIZATION OF WELDING COMMERCIALLY PURE ALUMINUM AND COPPER FRICTION USING DESIGN OF EXPERIMENT

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Abstract

***A** relatively new solid state joining technique which is energy efficient, environment friendly and versatile has been emerged in recent years. This process is named as Friction Stir Welding (FSW) for joining dissimilar metals which are generally used in aerospace, shipbuilding, automotive and locomotive industries due to its various advantages. Aluminum and copper has many applications in the above mentioned fields along with many applications in the electrical industry due its high electrical conductivities. The optimization of process parameters plays a very important role to achieve good quality weld.*

In the present study, optimization of process parameters for joining of pure Aluminum and pure copper is done by Friction stir welding. Taguchi's L9 orthogonal array was applied to design the experiments to select these parameters. The four factors at three different levels were selected and the factors being tool rotational speed, traverse speed, plunge depth and interface position. Weld quality is analyzed by optical microscopy and scanning electron microscopy. Along with the calculation of volume fraction of porosity helps to find out the optimum parameters from the analysis 300rpm, 60mm/min, 4.93mm plunge depth and 1.2mm offset distance weld showed better joint with very less volume fraction of porosity than other set of parameters in the present study.

Keywords: *Friction stir welding Optimization, L9 orthogonal array, design of experiment.*

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1. INTRODUCTION

Friction Stir Welding (FSW) is a strong solid state joining process (the metal is not softened) that uses a third body apparatus to join two surfaces. Between the device and material, warmth is produced which prompts a delicate district close to the FSW device. It is then mechanically intermixes the two bits of metal at the spot of the joint, then the mollified metal (because of the lifted temperature) can be joined utilizing mechanical weight. (Which is connected by the apparatus), It is principally utilized on aluminium, and frequently on expelled aluminium (non-heat treatable composites), and on structures which need prevalent weld quality without a post weld heat treatment. [2]

It was imagined and tentatively demonstrated at The Welding Institute UK in December 1991. TWI holds licenses on the procedure, the first being the most enlightening.

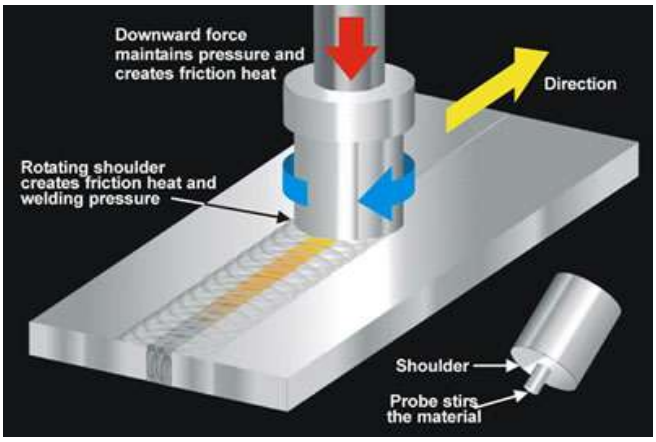


Fig 1: Depiction of the Friction Stir Welding of two plates sharing a butt joint

FSW is a strong state process which produces welds of high potential in hard to-weld materials, for example, aluminium, and is quick turning into the procedure of decision for assembling lightweight transport structures, for example, water crafts, trains and planes.

FSW, being a strong state, low-vitality information, repeatable mechanical procedure equipped for delivering high-quality welds in an extensive variety of materials, offers a conceivably bring down cost, earth benevolent answer for these difficulties. [3]

FSW is a strong state joining handle that makes superb, high-quality joints with low contortion and is fit for creating either butt or lap joints, in an extensive variety of material thicknesses and lengths.

In FSW, a round and hollow carried apparatus with a profiled pin is turned and dove into the joint range between two bits of sheet or plate material. The parts must be safely braced to keep the joint countenances from being constrained separated. Frictional warmth between the wear safe welding apparatus and the work pieces causes the last to mollify without achieving dissolving point, permitting the device to navigate along the weld line. The plasticized material, exchanged to the trailing edge of the apparatus pin, is fashioned through personal contact with the instrument shoulder and stick profile. On cooling, a strong stage bond is made between the work pieces.

2. METHODOLOGY

The methodology followed in the study is explained below:
1. Formulation of parameters using Design of experiments. Taguchi's method was employed to optimize the best weld.
2. Study of experimental procedures to be carried out while doing the FSW technique and post weld techniques.
3. 3-Axis (Vertical) Welding machine used to weld the plates (Copper to aluminum or aluminum to copper) after fixing the backing plates and base plates have been fixed and tightened properly with precision.
4. Plates to be removed after the weld are over, with precision, without disturbing the weld.
5. Samples to be cut in the Abrasive wheel cutting machine after proper dimensioning and marking.
6. Belt polishing machine (Grit size of 120) is used to then polish the cut samples.
7. After Belt polishing, Polishing is again done with the help of emery sheets with grit sizes of 220, 400, 600, 800, 1000, 1200 and 2000.
8. Cloth polishing is then done with silicon carbide (Grit size of 1200)
9. Diamond polishing with a diamond paste of Grit size in the level of a few microns is then done at last to give a proper mirror finishing to the sample.
10. Etching both the aluminum and the Copper sides with Keller's Reagent and Copper's Etchant respectively.
11. Stereo images are taken with the help of Stereo microscope.
12. Optical images are taken with the help of ZEISS Optical Microscope.
13. Porosity test using Image J software
14. Calculate the s/n ratio on the basis numbers of porosity present in weld to the find best weld.

3. RESULT AND DISCUSSION

3.1 Plan of Experiments

Taguchi techniques which consolidate the trial plan hypothesis and the quality misfortune capacity idea have been utilized as a part of FSW and procedures. The degrees of flexibility for three parameters in each of three levels were ascertained.

Level of Freedom (DOF) = number of levels - (1)
For every variable, DOF equivalent to: For (A);
DOF = 3 – 1 = 2 For (B);
DOF = 3 – 1 = 2 For (C);
DOF = 3 – 1 = 2 for (D)

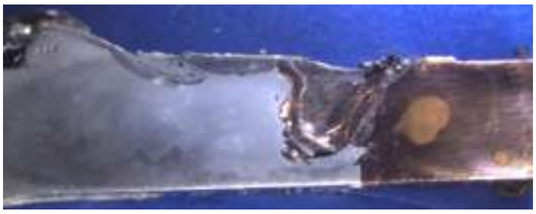
In this nine trials were carried out at various parameters. For this Taguchi L9 orthogonal exhibit was utilized, which has nine lines comparing to the quantity of tests, with three segments at three levels. L9 OA has eight DOF, in which 6 were allotted to three elements (every one 2 DOF) and 2 DOF For the motivation behind watching the level of impact of the procedure parameters in FSW, four components, each at three levels, are considered, as appeared in Table 1 .

Table 1: Depicts the process parameters employed in the study

	FACTORS			
Levels	Plunge depth in Mm	Traverse speed in rpm	Rotational speed in mm/min	Interface portion in mm
1	4.90	200	40	0
2	4.93	300	50	1.2
3	4.96	400	60	1.2

Using the above parameters, the experiments were performed to analyze the best combination of the FSW parameters to obtained good weldment. Three set of trials were conducted and the outcome of the experiments is been highlighted in the table 2.

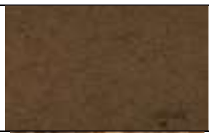
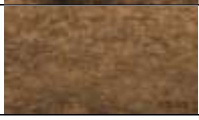
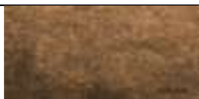
Table 2: The stereo microscopy images of the weldment

Stereo Microscopy Images After The Cloth Polishing		
Experiment no	**Magnitude at 1x**	**Magnitude at 0.7x**
1		
2		
3		
4		
5		
6		
7		
8		

9		

The optical images of the same is exhibited in the table 3.

Table 3: Optical Microscopy Images

Experiment no	Optical Microscopy Images After Etchant	
1		
2		
3		
4		
5		
6		
7		
8		
9		

3.2 Porosity A, B, C, D

Response table for signal noise ratios, Smaller is better.

Table 5: Response table for signal to noise ratios

Level	**A**	**B**	**C**	**D**
1	**-76.95**	**-78.83**	**-78.798**	**-76.78**
2	**-76.59**	**-76.36**	**-78.594**	**-78.79**
3	**-78.35**	**-76.70**	**-74.509**	**-76.32**
Best levels	**2**	**2**	**3**	**2**

4. CONCULSION

- Experiments are conducted as per designs of experiments (DOE) approach to characterize the FSW for Al – Cu
- The resources (material and time) required for the experiments are also minimum.
- In the present study it was observed that the optimum weld parameters is 4.93 plunge depth in mm, 300 RPM, Traverse speed 60 mm/min, 1.2 mm offset

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